Testing Cadmium-free Coatings

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Agenda

- Department of Defense direction
- Fastener coating issues
- Past testing
- Present testing
- Future testing

DoD Direction

- Office of the Secretary of Defense Directive
  - "Approve the use of alternatives [to hexavalent chromium (Cr^{6+})] where they can perform adequately for the intended application and operating environment."
- Executive Order 13423
  - Ensures agency reduces toxic/hazardous chemicals and materials acquired, used, or disposed of

DoD Direction

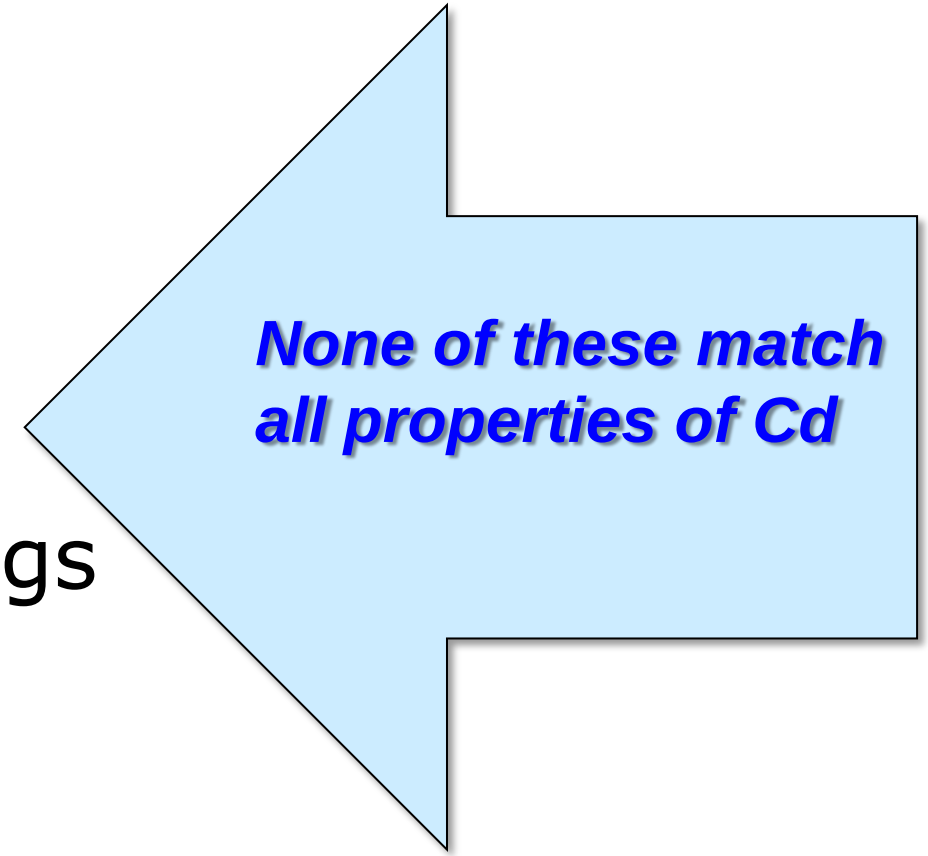
- Army Regulation AR 200-1
  - "Minimize the use of toxic and hazardous materials and processes in all life cycle phases of acquisition programs, logistics support, modification of existing weapons systems, and installation management.“
- Compliance with environmental permits increase Army Depot’s repair & waste treatment costs

Fastener Coating Issues

- No drop-in replacement that mimics all of Cadmium's (Cd) properties
- Too many alternatives to test
- No central authority driving commonality
- Galvanic compatibility with legacy systems
- Friction and joint clamp load

Fastener Coating Issues Cont'd

- Metallic Platings
  - Zinc (Zn)
  - Nickel (Ni)
  - Zinc Nickel (ZnNi)
  - Tin Zinc (SnZn)
- "Paint-like" Coatings
  - Zinc-Rich
  - Magnesium-Rich
  - Zinc Aluminum-Rich



Fastener Coating Issues Cont'd

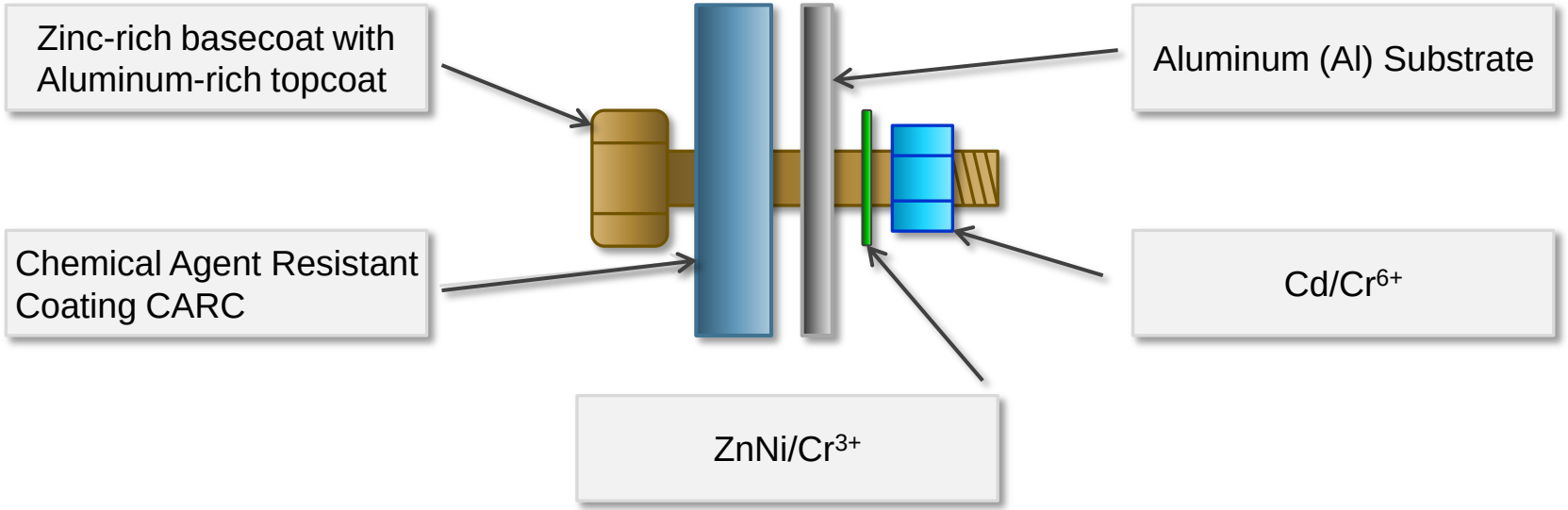
- Siloxane/Polysiloxane
- Silicate
- Polymer-based
- Zirconium-based

These passivation chemistries do not match all properties of Cr^{6+}

Either paint adhesion is reduced
Or
Corrosion protection is reduced

Fastener Coating Issues Cont'd

Risk of uncontrolled introduction of galvanic couples during sustainment



Fastener Coating Issues Cont'd

For the same torque…

Changing the Finish

↓

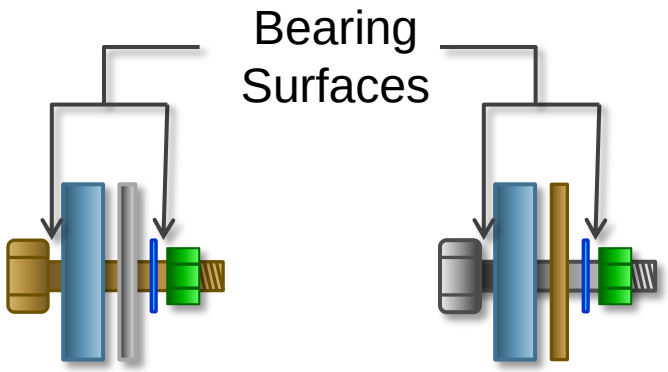
Changes the Friction

↓

Changes the Clamp Load

→ *…changing finishes may result in inadequate clamp load, joint loosening, stripped threads, broken fasteners*

Joint reliability



Past Testing

- Threaded Fasteners
- Electrical Connectors

Threaded Fastener Study

- Property Class Grade 8
  - 150 ksi tensile strength
  - 120 ksi min. proof load
- Sizes:
  - ⅜″ x 3″
  - ½″ x 3″
- Sample Size
  - Five for each test

Fastener Finish Study

- Six finishes evaluated for…
  - Torque at fixed clamp load (preload)
  - Effect of corrosion on rundown torque
  - Effect of corrosion on breakaway torque

Fastener Finish Study

FINISH	POST-TREATMENT	LUBRICANT
Cadmium	Hexavalent Chromium (Cr^{6+})	None
Zinc	Cr^{6+}	None
Zinc	Trivalent Chromium Process (TCP)	Enseal C22
Zinc Nickel	TCP	Enseal C22
High Purity Al	TCP	Enseal C22
Zn-rich two coat system	None	Integral to topcoate

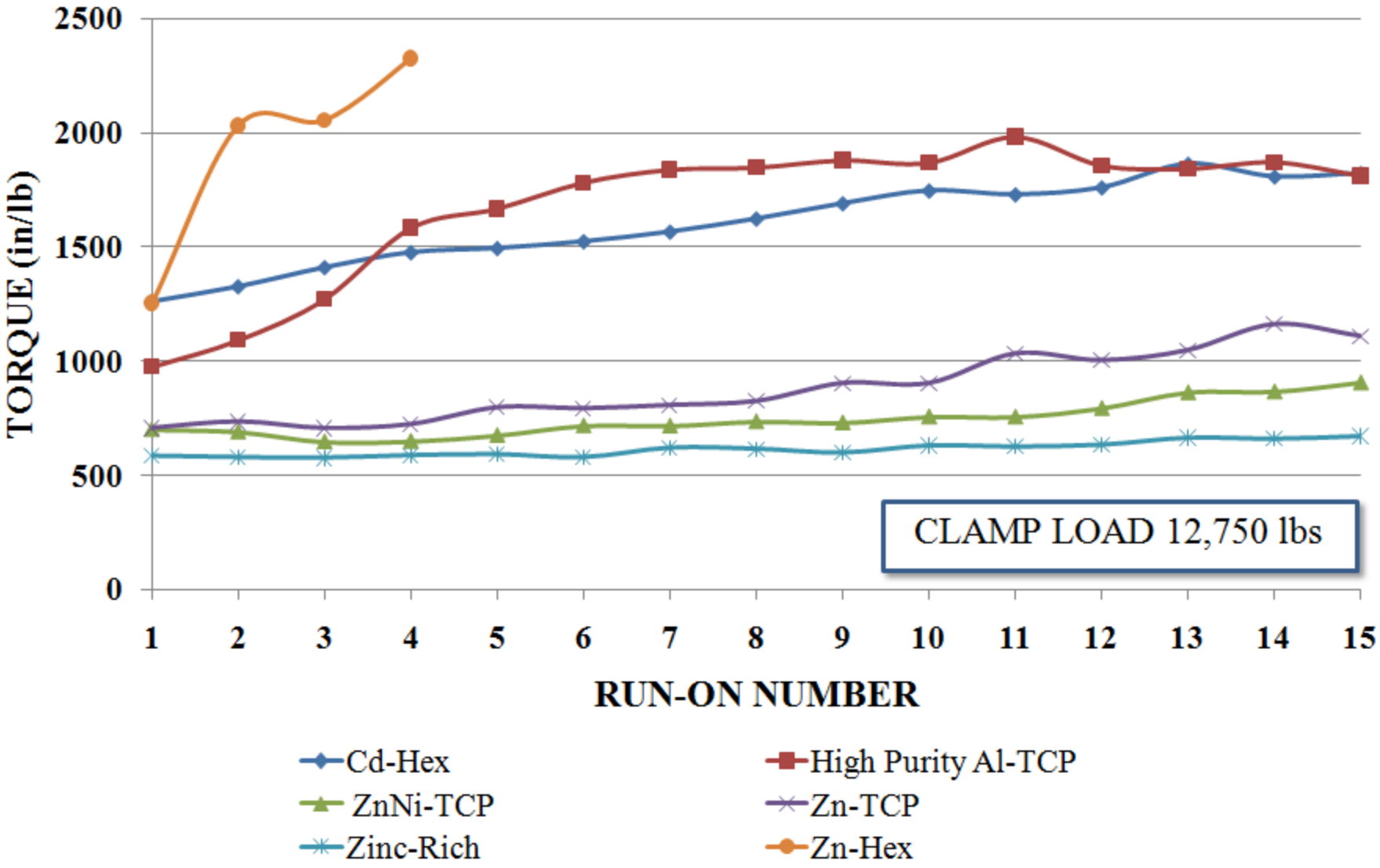
Clamp Load ½” Fasteners Target vs Actual

Plating	Average Clamp Load (lb)	Target Clamp Load (lb)
Cd/Cr^{6+}	12,736	12,750
Zn/Cr^{6+}	12,759	12,750
Zn/TCP	12,737	12,750
Zn-Ni/TCP	12,749	12,750
High Purity Al/TCP	12,747	12,750
Zn-rich two coat system	12,751	12,750

Clamp Load ⅜” Fasteners Target vs Actual

Plating	Average Clamp Load (lb)	Target Clamp Load (lb)
Cd/Cr^{6+}	6,965	6,950
Zn/Cr^{6+}	6,963	6,950
Zn/TCP	6,915	6,950
Zn-Ni/TCP	6,923	6,950
High Purity Al/TCP	6,964	6,950
Zn-rich two coat system	6,965	6,950

Rundown Torque for ½" Grade 8 Bolt
After 80 Cycles Cyclic Corrosion Testing



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Past Testing

Conclusions

- Torque value and clamp load within experimental error
- Corrosion performance equivalent or better
- Aluminum galvanic compatibility with legacy coatings
- High purity aluminum is closest to Cd

Past Testing Electrical Connectors

- Tested to MIL-DTL-38999
  - Corrosion, Salt Spray
  - Electromagnetic Compatibility (EMC) / Electromagnetic Interference (EMI)
  - Fluid Resistance
  - High Temperature Resistance
  - Mating and Un-mating Forces
  - Shell to Shell Conductivity
- Additional Tests
  - Corrosion, Cyclic
  - Corrosion, Scribed with Primer and Topcoat
  - Corrosion, Sulfur Dioxide
  - Durability in Humidity
  - Galvanic Corrosion Resistance (Compatibility)
  - Lubricity
  - Wear/Handling

Past Testing
Electrical Connectors

Coatings

- Al / TCP
- ZnNi / TCP
- ZnNi / Non-Chrome Passivation (NCP)
- Ni-PTFE 1
- Ni-PTFE 2
- Note: SnZn tested on flat panels

Past Electrical Connector Testing – Conclusions Problematic

Coated Coupons Run with Electrical Connectors	Vendor-Provided Coating Thickness Range (mils)	Average Measured Thickness (mils)
Cadmium / hex Cr	0.8 to 1.5	0.34
Al / TCP	0.6 to 1.0	0.03
ZnNi / TCP	0.8 to 1.5	0.93
ZnNi / NCP	0.7 to 1.2	0.89
SnZn / TCP	0.2 min.	0.33
SnZn / NCP	0.2 min.	0.42
Ni-PTFE*	(none provided)	1.55
PIN	0.8 to 1.5	1.38

*PTFE = Polytretrafluoroethylene

⅜” Fastener Clamp Load Target vs Actual

Coupons Run with Electrical Connectors	Vendor-Provided Coating Thickness (mils)	Average Measured Thickness (mils)
Cd/Cr^{6+}	0.8 to 1.5	0.34
Al / TCP	0.6 to 1.0	0.03
ZnNi / TCP	0.8 to 1.5	0.93
ZnNi / NCP	0.7 to 1.2	0.89
Ni-PTFE	(none provided)	1.55
PIN	0.8 to 1.5 per side	1.38
SnZn / TCP	0.2 minimum	0.33
SnZn / NCP	0.2 minimum	0.42

Current Testing

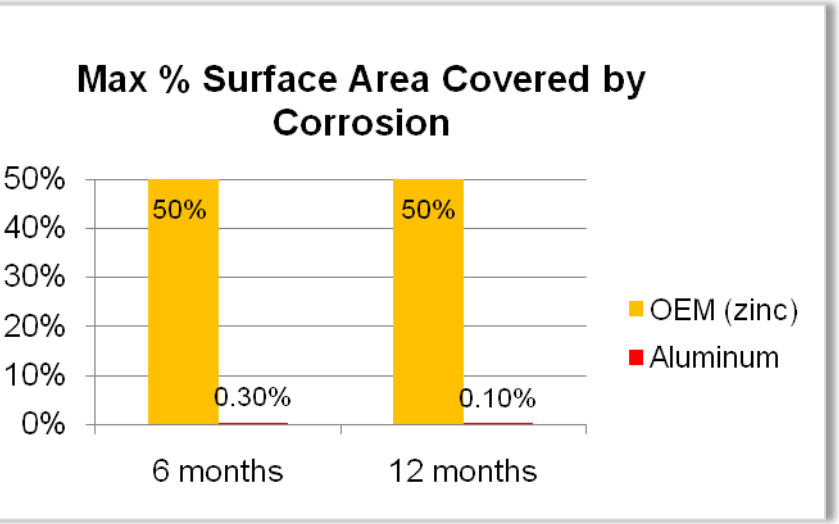
- High purity aluminum plated fasteners with TCP and electrocoat
  - Fluid resistance
  - Outdoor exposure
  - Torque-Tension testing
  - Lab cyclic corrosion test
- High purity Al coating on Stryker wheel stud and lugnut field exposure ongoing – threaded fastener

High Purity Aluminum Lugnut Field Demonstration

- Field testing confirms that electrodeposited, high purity Al outperforms zinc-rich coating
- HAZMAT reduced; performance improved
- Recommended single Cd replacement

Aluminum-Plated Lugs

OEM Zinc-Rich



Aluminum-Plated Lugs
1 Year – RV-0259-05

OEM Zinc Lugs Nuts
1 Year – RV-0259-05

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Future Testing of Electrical Connectors

- Cyclic corrosion
  - Lab cyclic corrosion testing
  - Outdoor exposure at Army test site
  - Un-scribed and Scribed connectors?
  - Galvanic - all coating combinations
- EMC / EMI
- Shell-to-Shell Conductivity

Future Testing of Electrical Connectors

- Fluid Resistance
- High Temperature Resistance
- Mating and Un-mating Forces
- Durability in Humidity
- Wear/Handling

Future Testing Electrical Connectors

- Coatings
  - Cadmium
  - Zinc-Nickel
  - High Purity Aluminum
  - Nickel/Composite Nickel
- Statistically significant sample sizes

Electrical Connector Summary

- Significant body of work testing coatings for electrical connectors
- Receptive to adjusting this new work plan to avoid duplication

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